The Influence of Atmosphere-Ocean Interaction on MJO Development and Propagation

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LONG-TERM GOALS

The long-term goal of this project is to understand the role of the atmosphere-ocean interaction processes in the initiation, maintenance and propagation of Madden Julian Oscillation (MJO). Better grasp of the atmosphere/ocean feedbacks in the Tropics will allow formulating more accurate parameterizations of the air-sea interface in the forecasting models. It will contribute to improved predictability of the MJO and other coupled phenomena on various special and temporal scales.

OBJECTIVE

The objective of this research is to examine how atmospheric fluxes associated with convection influence the structure of salinity and temperature in the oceanic mixed layer in the Indian Ocean. The variability of SST and formation of salinity lenses is emphasized. The feedback of the sea surface variability on the formation of convective cells associated with the MJO will be assessed.

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APPROACH

The three ways coupled atmosphere-ocean-wave model (two-way interactive between COAMPS®[1] and NCOM; one way interactive with SWAN) is used to examine air-sea interaction in the Indian Ocean during the active and inactive phase of MJO. The model is used for process studies that aim to evaluate atmosphere-ocean feedbacks and their influence on MJO development, and for forecasting of air sea interaction in the Indian Ocean basin and its influence on MJO. The impact of various physical processes and their parameterizations on simulated on predictability of MJO is examined.

The integral part of this project is participation in the field experiment. We provided forecasting support during the field phase and we will use the experiment data to constraint/evaluate modeling results. The field phase of this project is associated with DYNAMO, which is the US contribution to the interactional experiment CINDY 2011.

WORK COMPLETED

In the past year, we primarily worked on:

1. Model validation using the available DYNAMO observations
2. Analyzing the DYNAMO results from COAMPS forecasts and field observations obtained though collaborations with other DYNAMO PIs
3. Examining the impact of atmosphere-ocean interaction on convection during DYNAMO

RESULTS

Coupled COAMPS[2] forecasts during the DYNAMO field phase: model validation.

The 4 day forecasts preformed during the DYNAMO IOP were evaluated using the field data obtained from individual DYNAMO PI. The data included the rawinsondes from the SSA, air-sea flux measurement provided by the National Oceanic and Atmospheric Administration's Earth's Systems Research Laboratory (NOAA ESRL), University of Connecticut, and Oregon State University on board *R/V Revelle*, the shipboard Conductivity, Temperature, and Depth (CTD) from *Revelle* provided by Oregon State University, autonomous underwater vehicles (sea glider) from the University of East Anglia, England, three DYNAMO moorings from the University of Washington (UW), the 0.25 degree resolution multi-sensors satellite derived rain rate from TRMM-3B42, and Megatropic METEOSAT 7 high-resolution thermo IR.

Fig. 1 shows the comparison of the real-time COAMPS 6h forecasts of TPW from 1 Oct-30 Nov, 2011 at the Revelle site. The COAMPS bias in October is larger than November due to several model cold starts in October. Overall, COAMPS slightly under-predicts the amount of moisture in the atmosphere

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[2]COAMPS® is a registered trademark of the Naval Research Laboratory.

during both the onset of MJO1 and MJO2 but has a good agreement with all three sounding stations in the time period preceding and during the November MJO initiation.

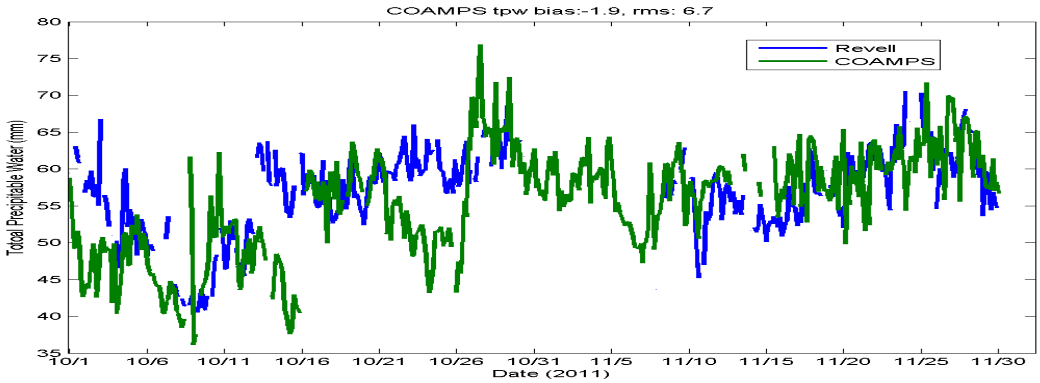
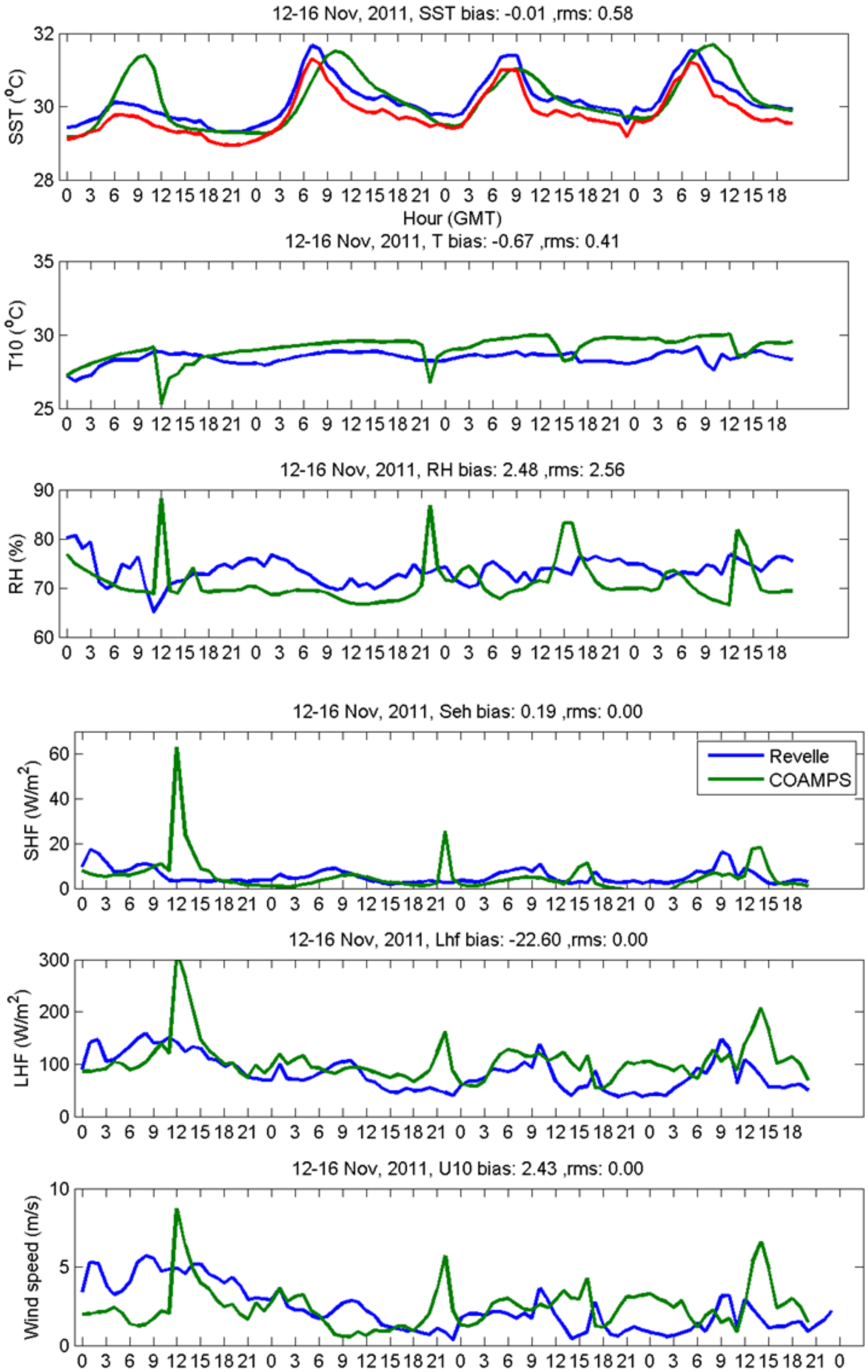


Figure 1. The total precipitable water from Revelle soundings and 6 h COAMPS forecasts

The Revelle observations of near surface sea temperature, the SST estimate after a correction for the cool skin (Fairall et al. 1996), 10-m temperature, humidity, sensible heat flux, latent heat flux, wind speed, net shortwave flux, longwave flux, and rain, compared with a 93h (~4-days) hindcast which have been interpolated in time and space to the Revelle location, for the suppressed phase preceding the November MJO, are shown in Fig.2. In general, the COAMPS generated values agree very well with the Revelle observations for all 10 parameters. The comparisons with observations show that COAMPS SST maxima lag the observations by a few hours but the peak magnitude of the COAMPS SST is closer to that of the observed near surface SST (Fig. 2a). Because of the bias in the long wave surface flux, the total heat flux into the ocean is overestimated by about 18 $W/m^{2.}$


12-16 Nov, 2011, SST bias: -0.01 ,rms: 0.58
SST (°C)
Hour (GMT)
12-16 Nov, 2011, T bias: -0.67 ,rms: 0.41
T10 (°C)
12-16 Nov, 2011, RH bias: 2.48 ,rms: 2.56
RH (%)
12-16 Nov, 2011, Seh bias: 0.19 ,rms: 0.00
SHF (W/m²)
Revelle
COAMPS
12-16 Nov, 2011, Lhf bias: -22.60 ,rms: 0.00
LHF (W/m²)
12-16 Nov, 2011, U10 bias: 2.43 ,rms: 0.00
Wind speed (m/s)

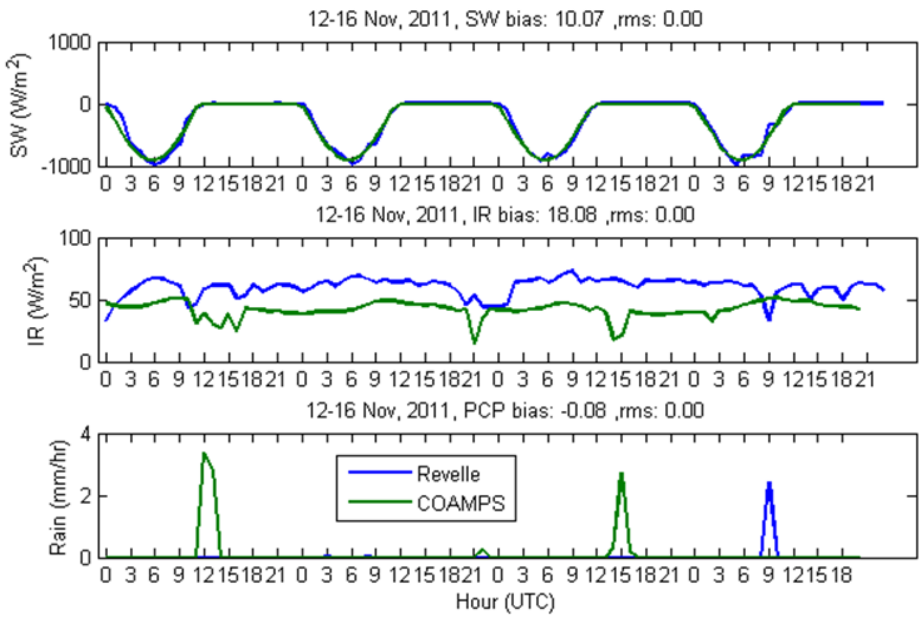


Figure 2. Comparisons of Revelle and COAMPS control simulation (from top to bottom) of (a) sea surface temperature (°C), (b) 10m air temperature (°C), (c) 10m relative humidity (%), (d) sensible heat flux (Wm-2), (e) latent heat flux (Wm-2), (f) wind speed (ms-1), (g) shortwave radiation (Wm-2), (h) longwave radiation (Wm-2), and (i) hourly precipitation (mm). Top panel shows the Revelle near surface SST (blue line) which is about few tens of degree higher than the SST corrected with the cool skin effect (red line).

Comparisons of the ocean temperature and mixed layer depth with the observational data from Revelle CTDs, Sea glider and buoys (not shown) indicates that for the suppressed period COAMPS slightly underestimates the depth of the mixed layer – this may have some consequences for the air-sea coupling and will need to be investigated further as the new DYNAMO processed data becomes available.

***Atmosphere ocean interaction during the MJO suppressed phase and November MJO initiation*.**

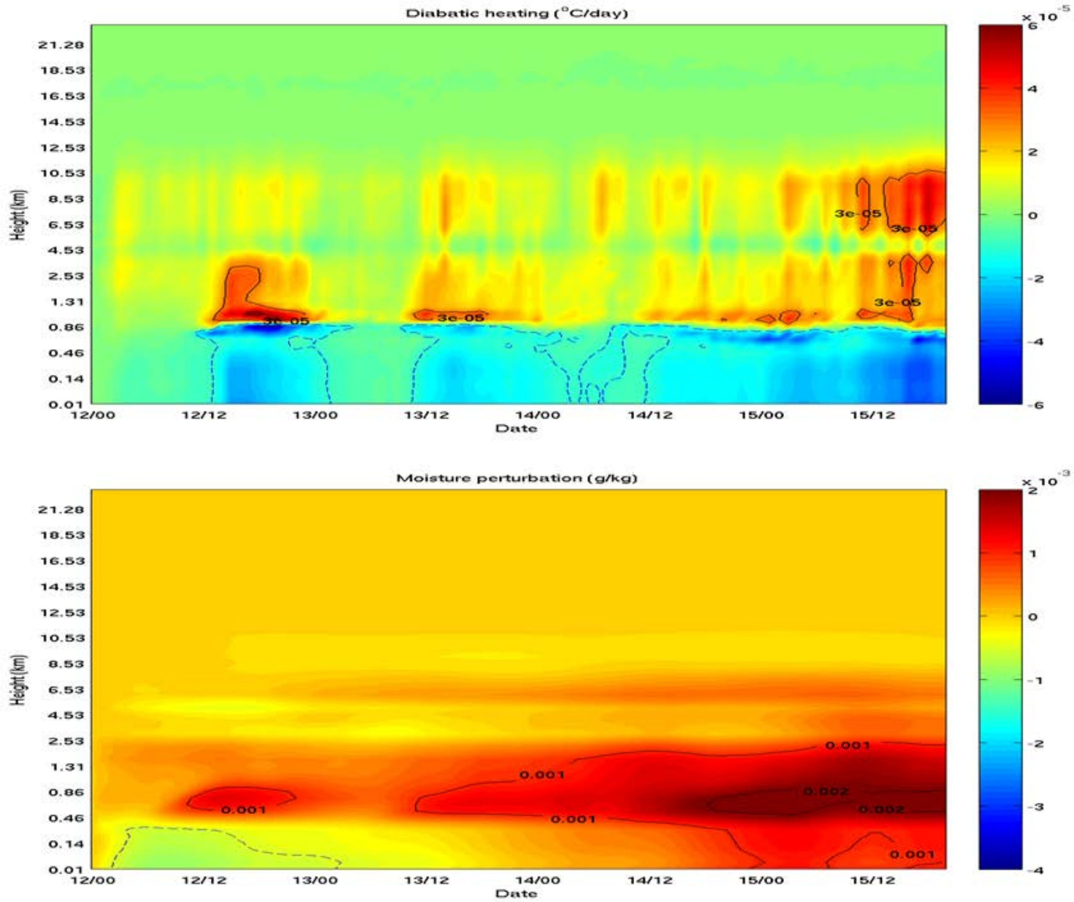


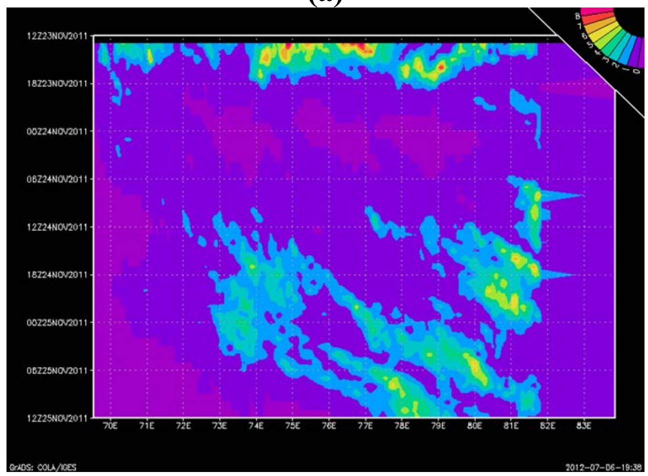
Figure 3. Time-height cross section of COAMPS grid 3 domain-averaged (a) diabatic heating, (b) perturbation mixing ratio.

The suppressed phase of the MJO, especially the period precedeing the development of the November MJO was studied using the observational data from the sounding array, Revelle surface fluxes and Sea-Glider observations. We hosted the PhD student (Dariusz Baranowski) who worked on the development of the warm layer as seen in the Sea Glider measurements. The large diurnal cycle in the upper ocean and large SST variability was observed at this time. The development of the warm layer in COAMPS was consistent with the glider observations although the COAMPS warm layer appeared to be slightly warmer and shallower than observations. The upper ocean variability contributed to development of afternoon convection during the suppressed period. Fig. 3 illustrates the convective activity during the suppressed phase and subsequent gradual moistening of the troposphere. In response to SST variability shown in Fig 2a the development of convective activity and gradual moistening of the atmosphere is observed. We propose a moisture resurgent hypothesis that describes a positive feedback loop of high SST –increase SST gradient - increase low-level convergence-increase moisture-increase precipitation combined with the transient large-scale equatorial waves that ultimately are responsible for the transition from MJO dry to moist phase. The diurnal variability of

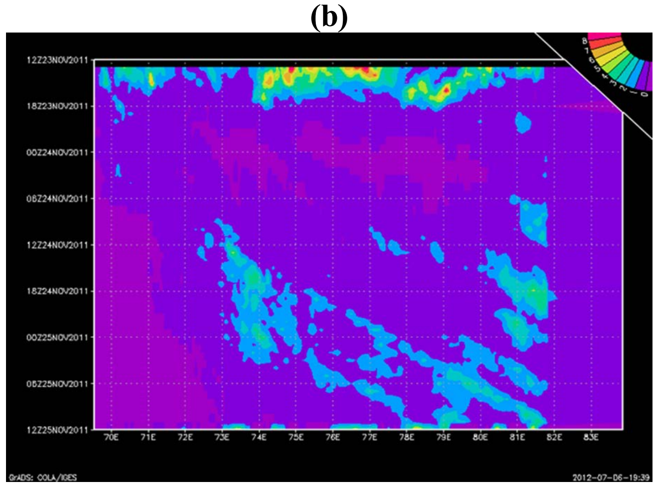
precipitation and diabatic heating that can be seen in Figs. 2 and 3 is not observed in the simulation with constant SST.

Our experiments indicate that the air-sea interaction impact is not limited to the MJO suppressed phase. As shown in Fig. 4 including the atmosphere ocean coupling increases the precipitation in the equatorial waves that are responsible for triggering of the November 24 MJO initiation.

(a)



(b)



(c)

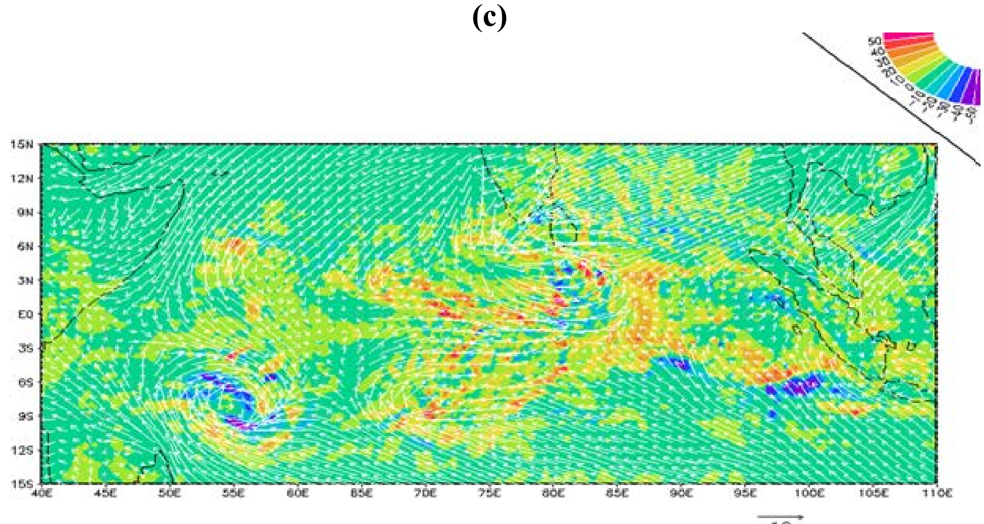


Figure 4. The impact of the atmosphere ocean coupling on precipiation in equatorial Kelvin waves during the November 24 MJO initation. (a) the time-latitude diagram of the convective preciptation in the inner COAMPS domain averaged over 2S-2N for the coupled forecast initatied on November 23. (b) the same for the uncoupled forecast (c) the spatial pattern of the preciptation difference for between the coupled and uncoupled forecats averaged for 24-48 forecast hours.

Spacial pattern of the rainfall difference between the coupled and uncoupled experiment shown in Fig.4c is consistent with the SST veriability observed for this time (not shown). In particular, the increase of preciptation at the leading edge of the Kelvin wave, near 85E is evident. In this area, dominated by low winds, convergence and large insolation the avergage SST and the diurnal range of SST are shown to inrease rapidly, leading to the early afternoon convection similar to that observed during the supressed phase.

The sudden inrease of equatorial winds observed on November 24 lead to the rapid development of Yoshida jet at the ocean surface. The jet remained string throughout the DYNAMO period with increasing westward extent, leading to increasing sea surface hight and increasing ocean heat content near Sumatra by the end of December (Fig. 6) similar to what was observed in satelite measurements described in (Shinoda et al 2013)

Our results idicate that the coupled COAMPS quite accurately describes the behaviour of DYNAMO MJOs in the atmosphere and the ocean and can be used to ellucidate the mechanism responsible for the atmosphere interaction in this area and contribute to deeper understanding of the MJO initation.

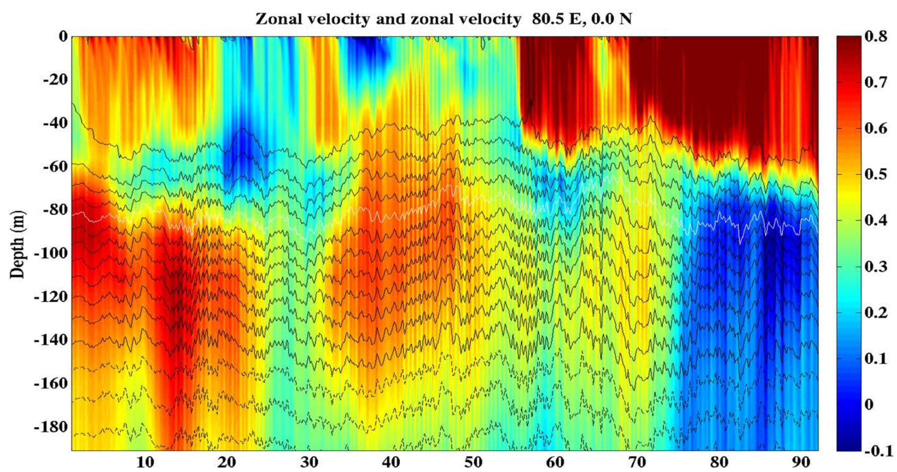


Figure. 5 Development of Yoshida Jet in response to November 24 MJO. The zonal velocity is indicated by shading the ocean temperature is shown by contours

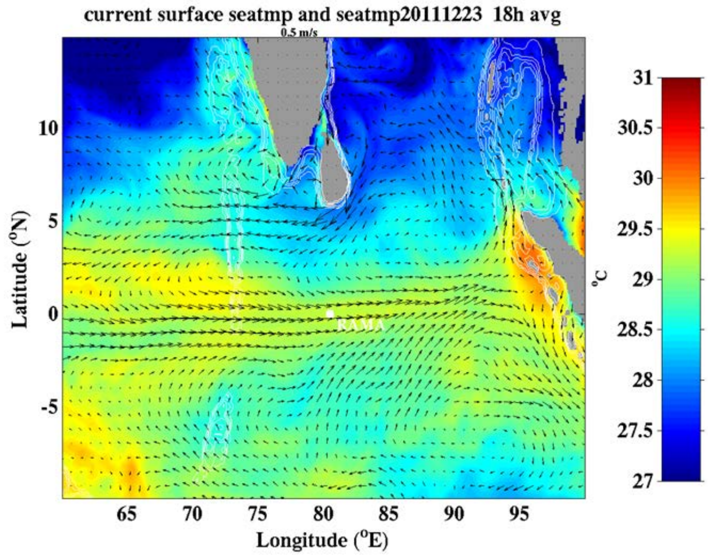


Figure 6: Surface currents and SST preceding December MJO

IMPACT/APPLICATIONS

The project will contribute to the better understanding of feedbacks between convection and atmospheric and oceanic mixed layer. The knowledge gained in this project will allow us to formulate and test more accurate parameterizations, the variance/co variance of coupling, and to improve the forecasting capability of COAMPS® and NAVGEM – especially the NAVGEM coupled to HYCOM.

For the DYNAMO field campaign, the model results help to integrate and explain the point observations and to combine them into a coherent description of MJO initiation.

TRANSITIONS

The improvements to coupled COAMPS® that will result from this work and can be transitioned to the 6.2 COAMPS project.

RELATED PROJECTS

This project is a part of the ONR Air-Sea interaction DRI and we collaborate with other PIs involved in this initiative as well as with the wide, international group of researchers involved in DYNAMO/CINDY experiment. Some issues related to impact of the diurnal SST variability on convection are also addressed under 6.1 Tyranny of Scales base projects. MJO development problems are also addressed in ONR-DRI 6.1-SeasnGBL and ONR Coupled COAMPS Extended Range MJO Prediction project.

PUBLICATIONS

Papers:

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MJO and Convectively Coupled Equatorial Waves Simulated by CMIP5 Climate Models
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Papers in preparation:

M. Flatau, S. Chen J. M. Schmidt, T. Jensen, T. Shinoda, D Baranowski: The role of the atmosphere ocean interaction in the initiation of November 24 2011 MJO DYNAMO event, as modeled by coupled COAMPS. To be submitted to MWR

Conferences/meetings/seminars

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2013: Shinoda, T., T. G. Jensen, M. K. Flatau, S. Chen, W. Han and C. Wang: Migration of Seychelles-Chagos Thermocline Ridge (SCTR) during DYNAMO. MJO Field Data and Science Workshop, March 4-8 2013, Hapuna Beach, HI

2012: Flatau, M., S. Chen, T. Shinoda, T. G. Jensen, D. B. Baranowski, and P. Flatau: The diurnal cycle in the atmosphere and ocean during DYNAMO. Poster. AGU Fall meeting, San Francisco, CA, December 3-7, 2012.